Mobrey Magnetic Level Switches

Functional Safety Manual

Contents

Magnetic Level Switch Functional Safety Manual

INTRODUCTION

Scope and Purpose of the Safety Manual

This safety manual contains the information to design, install, verify and maintain a Safety Instrumented Function (SIF) utilizing the Mobrey magnetic level switch.

The manual provides the necessary requirements to enable the integration of the horizontal point-level float switch when showing compliance with the IEC 61508 or IEC 61511 functional safety standards. It indicates all assumptions that have been made on the usage of the level switch. If these assumptions cannot be met by the application, the Safety Integrity Level (SIL) capability of the product may be adversely affected.

NOTE:
For product support, use the contact details on the back page.

Skill Level Requirement

System design, installation and commissioning, and repair and maintenance shall be carried out by suitably qualified personnel.

Terms, Abbreviations, And Acronyms

Basic Safety

Freedom from unacceptable risk of harm.

BPCS

Basic Process Control System – a system which responds to input signals from the process, its associated equipment, other programmable systems and/or an operator and generates output signals causing the process and its associated equipment to operate in the desired manner but which does not perform any safety instrumented functions with a claimed SIL greater than or equal to 1.

Fail-safe State

State where switch output is in the state corresponding to an alarm condition. In this condition the switch contacts will normally be open.

Fail Dangerous

Failure that does not respond to an input from the process (i.e. not switching to the fail-safe state).

Fail Dangerous Detected

Failure that is dangerous but is detected.

Fail Dangerous Undetected

Failure that is dangerous and that is not detected.

Fail No Effect

Failure of a component that is part of the safety function but that has no effect on the safety function.

Fail Safe

Failure that causes the switch to go to the defined fail-safe state without an input from the process.

FIT

FIT is the abbreviation for Failure In Time. One FIT is $1x10^{-9}$ failure per hour

FMEDA

Failure Modes, Effects, and Diagnostics Analysis.

Functional Safety

Part of the overall safety relating to the process and the BPCS which depends on the correct functioning of the Safety Instrumented System (SIS) and other protection layers.

HFT

Hardware Fault Tolerance.

Low demand

Mode of operation, where the frequency of demands for operation made on a safety-related system is no greater than twice the proof test frequency.

PFD_{AVG}

Average Probability of Failure on Demand.

SFF

Safe Failure Fraction – a fraction of the overall random failure rate of a device that results in either a safe failure or a detected dangerous failure.

SIF

Safety Instrumented Function – a safety function with a specified SIL which is necessary to achieve functional safety. Typically a set of equipment intended to reduce the risk due to a specified hazard (a safety loop).

SIL

Safety Integrity Level – a discrete level (one out of four) for specifying the safety integrity requirements of the safety instrumented functions to be allocated to the safety instrumented systems.

SIL 4 has the highest level of safety integrity, and SIL 1 has the lowest level.

SIS

Safety Instrumented System – an instrumented system used to implement one or more safety instrumented functions. An SIS is composed of any combination of sensors, logic solvers, and final elements.

Documentation and Standards

This section lists the documentation and standards referred to by this safety manual.

Table 1.
Associated Documentation

Documents	Purpose of Documents
IEC 61508-2: ed2, 2010	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
Exida EM 10/08-36 R001	FMEDA Report Version V1, Revision R2 for the Mobrey magnetic level switch with a F84 Float
IP101	Mobrey magnetic level switch Product Data Sheet
M310	Mobrey magnetic level switch Instruction leaflet

Table 2.
Associated Standards

Standards	Purpose of Standards
IEC 61508: ed2, 2010	Functional Safety of electrical/electronic/programmable electronic safety-related systems
IEC 61511 (ANSI/ISA 84.00.01-2004)	Functional safety - Safety instrumented systems for the process industry sector

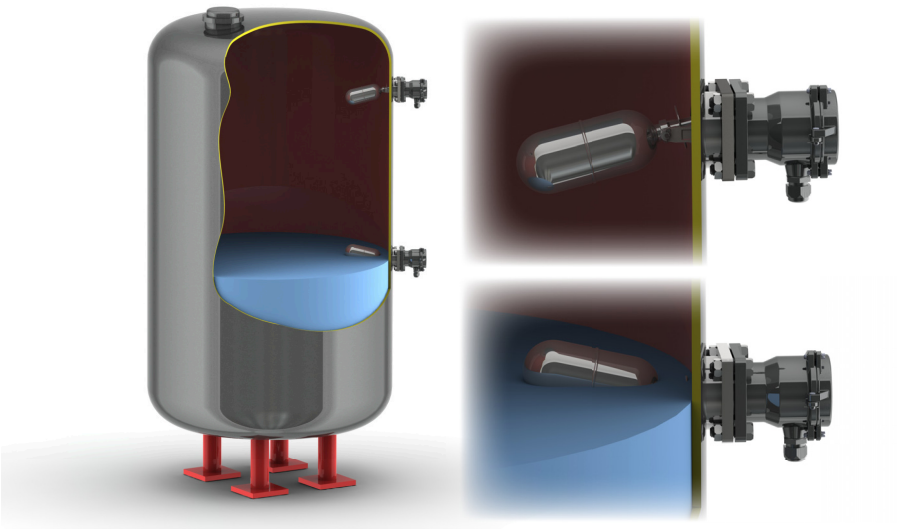
Horizontal Float Switch

PRODUCT DESCRIPTION

Level Switch Purpose

Mobrey magnetic level switches are ideal for high and low liquid level alarm, overfill alarm, and pump control duties.

Figure 1.
Application Example:
High and Low Level Alarm



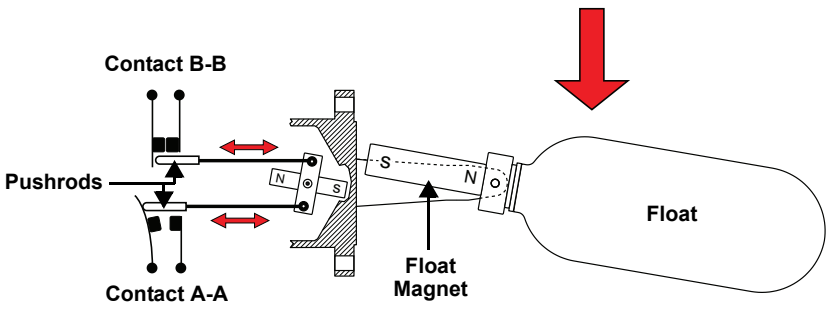
Operation Principle

The level switch is designed to open or close a circuit (“switch”) as a changing liquid level within a vessel passes the level of the float (the Switch Point).

When the process fluid level is below the Switch Point, contacts B-B are made and contacts A-A are open (Figure 2).

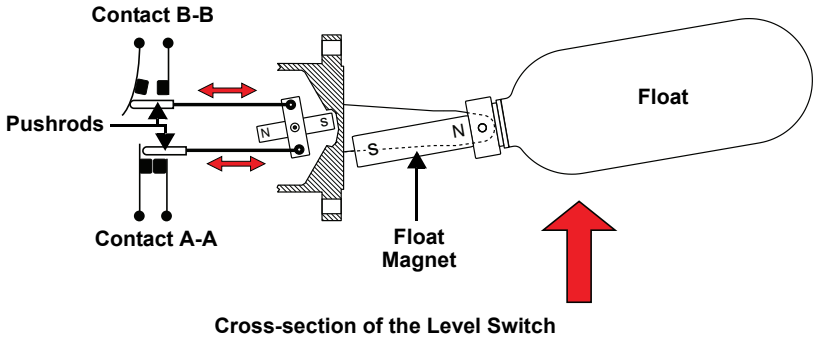
When the process fluid level is above the Switch Point, contacts A-A are made and contacts B-B are open (Figure 3).

Figure 2.
Level Decreases –
Float Pivots Downwards



Cross-section of the Level Switch

Figure 3.
Level Increases –
Float Pivots Upwards



NOTE:
For all product information and documentation downloads, visit www.mobrey.com.

Ordering Information

Level switch models fitted with options listed on pages 14 and 15 of this manual have been externally assessed and certified to IEC 61508.

A copy of the third party SIL certificate can be ordered from Mobrey (accessory model code L2049).

DESIGNING A SAFETY FUNCTION USING THE LEVEL SWITCH

Safety Function

A change in liquid level through the *operating range* of the float causes the switch to operate. It may be used in **high level** or **low level** safety related applications. In either case, it is recommended to use the set of contacts (A-A or B-B) which are Open in the Fail Safe State.

Environmental Limits

The designer of the SIF (Safety Instrumented Function) must check that the level switch is rated for use within the expected environmental limits. See the Mobrey product data sheet IP101 for environmental limits.

NOTE:
For all product information and documentation downloads, see www.mobrey.com.

Application Limits

It is very important that the SIF designer checks for material compatibility by considering process liquids and on-site chemical contaminants. If the Mobrey level switch is used outside the application limits or with incompatible materials, the reliability data and predicted SIL capability becomes invalid.

The construction materials of a Mobrey level switch are specified in the product data sheet and the product reference manual (see Table 1 on page 5).
Use the model code on the product label and the ordering information table and specification in these product documents to find out the construction materials.

Design Verification

A detailed Failure Modes, Effects and Diagnostics Analysis (**FMEDA**) report for the Mobrey magnetic level switch is available to download from the web sites www.mobrey.com and www.mobrey.com. The FMEDA report details all failure rates and failure modes as well as expected lifetime.

NOTE:
The FMEDA report is available from the **Safety** quick link at www.mobrey.com.
In the right-hand panel, there are SIL documents including the **FMEDA** report.

The achieved **Safety Integrity Level** (**SIL**) of an entire Safety Instrumented Function (SIF) design must be verified by the designer using a PFD_{AVG} calculation considering the architecture, proof test interval, proof test effectiveness, any automatic diagnostics, average repair time, and the specific failures rates of all equipment included in the SIF.

Each subsystem must be checked to assure compliance with minimum Hardware Fault Tolerance (HFT) requirements. When using the Mobrey level switch in a redundant configuration, a common cause factor of at least 5% should be included in the safety integrity calculations.

The failure rate data listed in the FMEDA report is only valid for the useful lifetime of the Mobrey level switch. The failure rates *increase* after this useful lifetime period has expired. Reliability calculations based on the data listed in the FMEDA report for mission times beyond the lifetime may yield results that are too optimistic, i.e. the calculated SIL will not be achieved.

SIL Capability

Systematic Integrity

The Mobrey level switch has met manufacturer design process requirements of Safety Integrity Level 2 (SIL 2). These are intended to achieve sufficient integrity against systematic errors of design by the manufacturer.

A Safety Instrumented Function (SIF) designed with the Mobrey level switch must not be used at a SIL higher than the statement without “prior use” justification by the end-user, or verification of diverse technology in the design.

Random Integrity

The Mobrey level switch is classified as a type A device according to Table 2 of the standard IEC 61508-2. Therefore, based on an Safe Failure Fraction (SFF) of between 0% and 60%, a design can meet SIL 1 with Hardware Fault Tolerance (HFT) = 0 and SIL 2 with HFT = 1 when the level switch is used as a single component in a sensor subsystem.

Safety Parameters

The failure rates given here are valid for the useful lifetime of the product, as described in the section “Useful Lifetime” on page 12.

NOTE:
The FMEDA report is available from the **Safety** quick link at www.mobrey.com. In the right-hand panel, there are SIL documents including the **FMEDA** report.

Table 3. Failure Rates for Level Switch 4-contact Versions – Types D and P

Failure Category	Failure Rate (FIT) (1)	
	Maximum Detection	Minimum Detection
Fail Safe Detected	0	0
Fail Safe Undetected	87	89
Fail Dangerous Detected	0	0
Fail Dangerous Undetected	195	193
Residual	34	34

(1) FIT is the abbreviation for Failure In Time. One FIT is $1x10^{-9}$ failure per hour.

Table 4. Failure Rates for Level Switch 6-contact Versions – Types D6, P6, H6, and B6

Failure Category	Failure Rate (FIT) (1)	
	Maximum Detection	Minimum Detection
Fail Safe Detected	0	0
Fail Safe Undetected	167	169
Fail Dangerous Detected	0	0
Fail Dangerous Undetected	275	273
Residual	34	34

(1) FIT is the abbreviation for Failure In Time. One FIT is $1x10^{-9}$ failure per hour.

Table 5. Failure Rates according to IEC 61508, 4-contact Versions – Types D and P (FIT)

Device	λ_{SD} (1)	λ_{SU}	λ_{DD}	λ_{DU}	SFF %
Maximum Detection	0	87	0	195	30.9
Minimum Detection	0	89	0	193	31.6

(1) FIT is the abbreviation for Failure In Time. One FIT is $1x10^{-9}$ failure per hour.

Table 6. Failure Rates according to IEC 61508, 6-contact Versions – Types D6, P6, H6, and B6 (FIT)

Device	λ_{SD} (1)	λ_{SU}	λ_{DD}	λ_{DU}	SFF %
Maximum Detection	0	167	0	275	37.8
Minimum Detection	0	169	0	273	38.3

(1) FIT is the abbreviation for Failure In Time. One FIT is $1x10^{-9}$ failure per hour.

Connection of the Level Switch to the SIS Logic Solver

The Mobrey level switch should be connected to the safety-rated logic solver which is actively performing the safety function as well as automatic diagnostics (if any) designed to diagnose potentially dangerous failures within the level switch.

NOTE:
For all product information and documentation downloads, visit www.mobrey.com.

General Requirements

- The system and function *response time* shall be less than the *process safety time*

  The Mobrey level switch will move to its defined safe state in less than this time with relation to the specific hazard scenario.
- All SIS components, including the Mobrey level switch, must be operational before process start-up
- The user shall verify that the Mobrey level switch is suitable for use in safety applications by confirming the float level switch *nameplate* and *model number* are properly marked
- Personnel performing maintenance and testing on the Mobrey level switch shall first be assessed as being competent to do so
- Results from periodic proof tests shall be recorded and periodically reviewed
- The Mobrey level switch shall not be operated beyond the useful lifetime as listed on page 12 (and in the specification section of the product document M310) without undergoing overhaul or replacement

INSTALLATION AND COMMISSIONING

NOTE:
For all product information and documentation downloads, visit www.mobrey.com.

Installation

The Mobrey level switch must be installed as described in the installation section of the product instructions leaflet M310. Check that environmental conditions do not exceed the ratings in the specification section.

The Mobrey level switch must be accessible for physical inspection.

Physical Location And Placement

The Mobrey level switch shall be accessible with sufficient room for cover removal and electrical connections, and allow for manual proof-testing to take place.

The switch point is determined by the location of the Mobrey level switch, and consideration must be given to allow the safe proof-testing of the level switch by forcing liquid to put the switch into its Fail-Safe state.

Electrical Connections

Wiring should be adequately rated and not be susceptible to mechanical damage. Electrical conduit is commonly used to protect wiring.

OPERATION AND MAINTENANCE

Proof-test Requirement

During operation, a low-demand mode SIF must be proof-tested. The objective of proof-testing is to detect failures within the equipment in the SIF that are not detected by any automatic diagnostics of the system. Undetected failures that prevent the SIF from performing its function are the main concern.

Periodic proof-tests shall take place at the frequency (or interval) defined by the SIL verification calculation. The proof-tests must be performed more frequently than or as frequently as specified in the SIL verification calculation in order to maintain the required safety integrity of the overall SIF. A sample procedure is provided in the section “Proposed Proof-test Procedure” on page 13.

Results from periodic proof tests shall be recorded and periodically reviewed.

Repair and Replacement

Repair procedures in the Mobrey product document M310 must be followed.

Notification Of Failures

In case of malfunction of the system or SIF, the Mobrey level switch shall be put out of operation and the process shall be kept in a safe state by other measures.

Mobrey Limited must be informed when the Mobrey level switch is required to be replaced due to failure. The failure shall be documented and reported to Mobrey Limited using the contact details on the back page of this safety manual. This is an important part of Emerson Process Management’s SIS management process.

SPECIFICATIONS

Useful Life

USEFUL LIFETIME

According to Section 7.4.9.5 of IEC 61508-2, a useful lifetime based on experience should be assumed.

Although a constant failure rate is assumed by the probabilistic estimation method (see FMEDA report), this only applies provided that the useful lifetime(1) of components is not exceeded. Beyond their useful lifetime, the result of the probabilistic calculation method is therefore meaningless as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the subsystem itself and its operating conditions.

This assumption of a constant failure rate is based on the bathtub curve. Therefore, it is obvious that the PFD_{AVG} calculation is only valid for components that have this constant domain and that the validity of the calculation is limited to the useful lifetime of each component.

Based on general field failure data and manufactures component data, a useful life period of approximately **10 to 15 years** is expected for the Mobrey level switch.

When plant experience indicates a shorter useful lifetime than indicated here, the number based on plant experience should be used.

(1) Useful lifetime is a reliability engineering term that describes the operational time interval where the failure rate of a device is relatively constant. It is not a term which covers product obsolescence, warranty, or other commercial issues.

PROPOSED PROOF-TEST PROCEDURE

According to Section 7.4.3.2.2 (f) of the standard IEC 61508-2, proof-tests shall be undertaken to reveal dangerous faults which are undetected by diagnostic tests. This means that it is necessary to specify how dangerous undetected faults which have been noted during the Failure Modes, Effects, and Diagnostic Analysis can be detected during proof-testing.

Suggested Proof-test

The suggested proof-tests (Tables 7 and 8) consist of switch operation tests in-situ.

Table 7.
Suggested Proof-test
(Low Level Alarm)

Step	Action
1	Inspect the accessible parts of the level switch for any leaks or damage
2	Bypass the safety function and take appropriate action to avoid a false trip
3	Disable any **filling** mechanism and drain the vessel to force the switch to the fail-safe state and confirm that the Safe State was achieved and within the correct time. **INDEPENDENT PRECAUTIONS MUST BE TAKEN TO ENSURE THAT NO HAZARD CAN RESULT FROM THIS OPERATION**.
4	Reinstate the **filling** mechanism so that the vessel refills and confirm that the normal operating state of the switch was achieved.
5	Remove the safety function bypass and otherwise restore normal operation

Table 8.
Suggested Proof-test
(High Level Alarm)

Step	Action
1	Inspect the accessible parts of the level switch for any leaks or damage
2	Bypass the safety function and take appropriate action to avoid a false trip
3	Disable any **drain** mechanism and fill the vessel to force the switch to the fail-safe state and confirm that the Safe State was achieved and within the correct time. **INDEPENDENT PRECAUTIONS MUST BE TAKEN TO ENSURE THAT NO HAZARD CAN RESULT FROM THIS OPERATION**.
4	Reinstate the **drain** mechanism so that the vessel refills and confirm that the normal operating state of the switch was achieved
5	Remove the safety function bypass and otherwise restore normal operation

Proof Test Coverage

The Proof Test Coverage for the tests listed in the section “Proposed Proof-test Procedure” may be considered to be 100%, covering all components of the Mobrey level switch.

LEVEL SWITCHES CERTIFIED TO IEC 61508

Tables 9, 10, and 11 lists all of the Mobrey magnetic level switch options that are certified to IEC 61508. In general, this is the entire range with the exception of the marine versions, pneumatic switch mechanisms, and some floats.

Refer to Mobrey product data sheet IP101 for the full specifications.

Table 9. Level Switches for General Purpose Applications (Stainless Steel Wetside)

Model	**Product Description**		
S	Switch		
Flange (Head)		**Flange (Head)**	
36	Mobrey A	431	EN 1092-1 PN 16 (DN 125)
190	Mobrey A	417	EN 1092-1 DN 65 PN 40 (DN 65)
440	3 in. ASME B16.5 Class 150 RF	418	EN 1092-1 PN 40 (DN 80)
441	4 in. ASME B16.5 Class 150 RF	419	EN 1092-1 PN 40 (DN 100)
424	3 in. ASME B16.5 Class 300 RF	433	EN 1092-1 PN 40 (DN 125)
425	4 in. ASME B16.5 Class 300 RF	434	EN 1092-1 PN 40 (DN 150)
489	3 in. ASME B16.5 Class 600 RF	488	EN 1092-1 PN 63 (DN 80)
490	3 in. ASME B16.5 Class 900 RF	435	EN 1092-1 PN 63 (DN 100)
428	EN 1092-1 PN 16 (DN 65)	436	EN 1092-1 PN 63 (DN 125)
429	EN 1092-1 PN 16 (DN 80)	437	EN 1092-1 PN 63 (DN 150)
430	EN 1092-1 PN 16 (DN 100)		
Switch Mechanism			
D	Electrical: 2 independent Single Pole Single Throw (SPST) contact sets		
P	As Type D but with *gold plated contacts*		
D6	Electrical: 2 independent circuits of double pole changeover contact sets		
P6	As Type D6 but with *gold plated contacts*		
H6	As Type D6 but with *gold plated contacts* and *hermetically sealed moving parts*		
B6	As Type H6 but *approved for Zone 2 areas*		
Enclosure / Housing			
A	Aluminum alloy		
Float			
F84	General purpose e.g. high/low alarm, 316 SST		
F93	Shrouded for dirty liquids, 316 SST		
F96	General purpose e.g. high/low alarm, 316 SST		
F98	General purpose e.g. high/low alarm, 316 SST		
F104/+	Cranked arm: horizontal or vertical, 316 SST		
F106	General purpose e.g. high/low alarm, 316 SST		
F107	General purpose e.g. high/low alarm, 316 SST		
Typical Model Number: S 36 D A / F84			

Table 10. Level Switches for General Purpose Applications (Aluminum Bronze Wetside)

Model	Product Description
S	Switch
Flange (Head)	
01	Mobrey A flange
Switch Mechanism	
DB	Electrical: 2 independent Single Pole Single Throw (SPST) contact sets
PB	As Type DB but with *gold plated contacts*
D6B	Electrical: 2 independent circuits of double pole changeover contact sets
P6B	As Type D6B but with *gold plated contacts*
Float	
F84	General purpose e.g. high/low alarm, 316 SST
F93	Shrouded for dirty liquids, 316 SST
F104/+	Cranked arm: horizontal or vertical, 316 SST
Typical Model Number: S 01 DB / F84	

Table 11. Level Switches for Hazardous Area Applications

Model	Product Description
S	Switch
Flange (Head)	
250	Mobrey G, 316 Stainless Steel
275	Mobrey G, Gunmetal
256	3 in. ASME B16.5 Class 150 RF
257	4 in. ASME B16.5 Class 150 RF
278	6 in. ASME B16.5 Class 150 RF
251	3 in. ASME B16.5 Class 300 RF
254	4 in. ASME B16.5 Class 300 RF
260	3 in. ASME B16.5 Class 600 RF
261	3 in. ASME B16.5 Class 900 RF
253	EN 1092-1 PN 40 (DN 80)
255	EN 1092-1 PN 40 (DN 100)
269	EN 1092-1 PN 40 (DN 125)
272	EN 1092-1 PN 63 (DN 80)
268	EN 1092-1 PN 63 (DN 100)
270	EN 1092-1 PN 63 (DN 125)
271	EN 1092-1 PN 63 (DN 150)
Switch Mechanism	
D	Electrical: 2 independent Single Pole Single Throw (SPST) contact sets
P	As Type D but with *gold plated contacts*
D6	Electrical: 2 independent circuits of double pole changeover contact sets
P6	As Type D6 but with *gold plated contacts*
H6	As Type D6 but with *gold plated contacts* and *hermetically sealed moving parts*
Enclosure / Housing	
A	Aluminum alloy
G	Gunmetal
X	Use ‘AX’ or ‘GX’ for applications with ambient temperatures –4 to –76 °F (–20 to –60 °C)
Float	
F84	General purpose e.g. high/low alarm, 316 SST
F185	General purpose e.g. high/low alarm, Alloy 400
F96	General purpose e.g. high/low alarm, 316 SST
F98	General purpose e.g. high/low alarm, 316 SST
F104/+	Cranked arm: horizontal or vertical, 316 SST
F106	General purpose e.g. high/low alarm, 316 SST
F107	General purpose e.g. high/low alarm, 316 SST
Typical Model Number: S 250 D A / F84	

Horizontal Float Switch

Functional Safety Manual
M310/FSM, Rev AA
January 2012

Mobrey Level Solutions

Emerson provides a wide range of Mobrey products for level measurement applications.

POINT LEVEL DETECTION

Vibrating Fork Liquid Level Switches

For high and low alarms, overfill protection, pump control, including wide pressure and temperature requirements, and hygienic applications. Flexible mounting. Immune to changing process conditions and suitable for most liquids.

- Mobrey Mini-Squing (Compact)
- Mobrey Squing 2 (Full-featured)

Ultrasonic Gap Sensor Liquid Level Switches

For use in non-hazardous industrial processes to detect high or low liquid levels and liquid interface. Immune to changing density, and wide dielectric and pH variations. Suitable for use in most clean and non-aerated liquids, with options for sludges and slurries.

Float and Displacer Liquid Level Switches

Mobrey electromechanical float and displacer level switches are ideal for alarm and pump control duties, especially in critical applications or hazardous areas.

- Mobrey Horizontal Level Switches
- Mobrey Vertical Level Switches

Chambers are available for external mounting of these level switches on process vessels.

Dry Products Level Switches

For high and low level alarms. Including threaded mounting connections, extended lengths, high temperature capability, and multiple detection techniques. Suitable for a wide variety of powders, granules, and free flowing solids with wide variations in bulk densities.

- Mobrey VLS Series – Vibrating Rod Level Switch
- Mobrey PLS Series – Paddle Level Switch

CONTINUOUS MEASUREMENT

Ultrasonic Continuous Level Transmitters and Controllers

Top mounted, non-contacting for simple tank and open-air process level measurements. Unaffected by fluid properties such as density, viscosity, dirty coating, and corrosiveness. Intrinsically Safe versions are available for operating in hazardous areas.

- Mobrey MSP Series Ultrasonic Level and Flow Transmitters
- Mobrey MCU900 Series Universal Controllers

Ultrasonic Sludge Density Blanket Monitoring and Control

Ultrasonic in-line pipe or tank mounted sensors for sludge density measurement and control, and top mounted ultrasonic sensors for continuous measurement of sludge blanket level in Industrial and Municipal effluent treatment processes.

- Mobrey MSM400 – Sludge Density Monitor
- Mobrey MSL600 – Sludge Blanket Level Monitor

Displacer Continuous Level Measurement

Top mounted in a vessel or externally mounted in a vertical chamber. For use in hazardous areas.

- Mobrey MLT100 – Displacer Level Transmitter

Hydrostatic Continuous Level Transmitter

For level measurements in non-pressurized tanks where in-tank problems such as foaming, vapor layers, and temperature gradients prohibit the use of other instrumentation.

- Mobrey 9700 Series hydrostatic electronic level transmitters

SPECIALIZED CONDUCTIVITY

Conductivity Water and Steam Interface Monitoring

Steam/water interface level gauges using specialized, high performance conductivity probes in external columns and manifolds, ideal for steam plants where reliable and redundant indication of boiler water level and turbine protection is critical.

- Hydratect 2462 – Water/Steam detection Systems
- Hydrastep 2468 – Water/Steam Monitoring Systems

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